An Ecological Survey of the Bourland Meadow Candidate Research Natural Area on the Stanislaus National Forest

Item 2 Order No. 896-PSW-75

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INTRODUCTION

Bourland Meadow Candidate Research Natural Area encompasses 406 ha between 2,195 and 2,415 m elevation on the west slope of the Sierra Nevada (Stanislaus National Forest). The proposed natural area comprises the uppermost watershed of Bourland Creek extending from $38^{\circ}6'30''$ to $38^{\circ}8'$ N. Latitude and from $119^{\circ}53'$ to $119^{\circ}55'$ Longitude (Figure 1). Emmigrant Basin Primitive Area lies along the southeast boundary of this region, while boundaries to the south and northwest would be with multiple use National Forest land. The northeast to southwest orientation of Bourland Creek results in at least 75% of terrain within the study area possessing either southeast or northwest exposure.

Red fir forest is the predominant vegetation although significant areas of lodgepole pine forest and aspen also occur about the lower margins and along the northeast boundary of Bourland Meadow, respectively. Exposed south slopes, ridge crests, and open rocky areas possess scrub associations dominated by Huckleberry Oak which occurs either alone or in association with open grown coniferous species. Open grown red fir and lodgepole pine form another scrub forest type on coarse sandy soils. This study presents a general ecological description of forest vegetation within the proposed Bourland Meadow Research Natural Area emphasizing composition, growth rates, and structure of coniferous types.

PROCEDURE

Vegetation was field mapped according to dominant species and results transcribed onto an enlarged 15 min. series U.S. Geological Survey topographic sheet for Pinecrest, California. Sites believed representative of forest vegetation within this region were subsequently analyzed using 75 x 100 ft. (0.07 ha) plots with the long axis parallel to slope direction. Woody and herbaceous vegetation was evaluated at each site using tabular comparison of Braun-Blanquet (Mueller-Dombois and Ellenberg, 1974). Arboreal species 5.08 cm dbh or greater were evaluated using count-plot methods (cover %, density, and basal area) to produce an importance value (Curtis and McIntosh, 1951). Heights of all conifers between 10 cm high up to 5 cm dbh were also measured. Numbers of seedlings less than 10 cm tall were evaluated for 20 ft. square (37.2 m^2) plots nested within the northwest and southeast corner of each 0.07 ha study site. Landscape factors (slope, aspect, and elevation) were also recorded for each study site.

Conifer growth was evaluated using site index (Avery, 1967) based on height and age at breast height (1.4 m). Sapling growth rates were obtained for selected trees less than 5 cm dbh by cutting and aging stems at 76 cm intervals. This practice was not employed where seedling establishment was believed limiting to density of mature trees. Heights of trees over 3 m tall were determined with a slope corrected Spiegal Relaskop.

Age-diameter data were used to estimate age-size class

distribution (survivorship curves) for conifers. Survivorship curves are log densities of each species per size class used to analyze successional trends (Jackson and Faller, 1973). Nomenclature follows Munz and Keck (1959) and Munz (1968).

RESULTS

Vegetation

Red fir forest (Society of American Foresters cover type 207) (S.A.F., 1954) extends over 229.5 ha or 57% of the proposed natural area (Figure 2). Four dominants may be associated with *Abies magnifica*: *Pinus contorta* ssp. *murrayana*, *P. monticola*, *P. jeffreyi*, and *Abies concolor*, although none were found either singly or in combination to comprise over 25% of total tree stratum cover (Table 1). Importance values for *Abies magnifica* are above 200 throughout the cover type with total red fir cover usually exceeding 40%. *Abies magnifica* basal area varies between 30 and 80 m^2/ha (plots 21-12 of Figure 3). Frequency is highly variable, ranging between 150 and 1,808 stems/ha and will be discussed with stand structure and succession (pages 9-12).

Four subtypes can be recognized within red fir forest: *Abies magnifica* - *Pinus contorta* stands (Am Pc in Figure 2), *Abies magnifica* - *Pinus monticola* - *Pinus contorta* stands (Am Pm Pc), *Abies magnifica* - *Abies concolor* stands (Am Ac), and *Abies magnifica* - *Abies concolor* - *Pinus jeffreyi* stands (Am Ac Pj).

Abies magnifica - *Pinus contorta* forests cover 98 ha of

well drained northwest exposures (Figure 2). Pinus monticola occurs as an additional associate particularly within 45 ha of Abies magnifica - Pinus contorta forest at the head of Bourland Creek where forests are underlain by Mesozoic granitic rock (Koenig, 1963) (The remainder of the study region possesses Pliestocene volcanic substrate excepting meadow sites which are underlain by quaternary alluvial deposits).

On southeast exposures Abies concolor is the principal associate within 31 ha of red fir forest (Another 30.5 ha of mixed red and white fir forest with southeast exposure were logged in the extreme NW corner of the Natural Area during 1967). Abies concolor is particularly within open stands along the ecotone between red fir and aspen forests (Ac - Am forest of Figure 2, plot 7, 21 in Figure 3). Open Abies concolor - A. magnifica stands are also characterized by Ceanothus cordulatus. Pinus jeffreyi occurs within 25 ha of Abies magnifica - A. concolor forest where a due south aspect is created by a slight alteration in the NE to SW orientation of ridges forming the Bourland Creek watershed (Figure 2).

Subdominant (herbaceous) species common throughout Bourland Meadow red fir forests are: Viola purpurea, Pedicularis semibarbata, Smilacina amplexicaulis, Erigeron peregrinus v. angustifolius, Kelloggia galioides, Thalytrichum fendleri, Chrysopis breweri, Hieracium albiflorum, Phacelia hydrophylloides, Pyrola picta, and Pterospora andromedia (Table 1). Additional species common within red fir forest which are frequent in more open vegetation types include:

Collinsia parviflora, Bromus marginatus, Poa bolanderi, Monardella odoratissima, Streptanthus tortuosa, Allium companulatum (Table 1). Unlike dominant associates within the red fir forest, there is no evidence for segregation of subdominant taxa according to slope, aspect or elevation. Presence versus absence of fir-type overstory appears to be the primary criterion in determining types of subdominant species present.

Approximately 4 % or 17 ha of the Bourland Meadow Candidate Research Natural Area are classified as lodgepole pine forest (cover type 218). Pinus contorta may exist as nearly pure stands adjacent to wet meadows (plot 19; Table 1) or as forests on dry slopes bordering meadows (plot 4). "Wet" Pinus contorta forests occur over 15.5 ha, principally about Bourland Meadow (Figure 2). Lodgepole pine is often the only arboreal species present, although Populus tremuloides, Abies magnifica and Abies concolor may also occur (the latter two usually as invaders). Cover, frequency and basal area of Pinus contorta are high with Importance Values equaling or just under 300 (Figure 3). Subordinate taxa of "wet" Pinus contorta sites are essentially those found within wet meadows and include: Dodecatheon alpinum, Senecio triangularis, Veratrum californicum and species of Carex, Cyperus, Juncus, Melica, Viola, Bromus, Gentiana, Erysimum and others (Table 1). Subordinate taxa in dry Pinus contorta forests include species associated with red fir forest (Kelloggia galioides, Viola purpurea), widespread species

characteristic of semi-open forest sites (Poa bolanderi, Bromus marginatus, Allium campanulatum, Elymus glaucus, Galium aparine, Montia perfoliata, Ribes roezlii) and "dry" meadow species (Rumex paucifolius, Calachortus leichtlinii, Lupinus densiflorus, Brodea exioides v. lugens, Castilleja lemonii, Cryptantha sp., Lingusticum grayii) (Table 1).

Scrubby Pinus contorta and Abies magnifica stands occur over 36.5 ha of dry meadow terrain interspersed among true red fir forest (Dm Pc Am stands of Figure 2). Density of both dominant species appears to be limited by seedling establishment. Once a tree does become established, height growth is strongly influenced by stem breakage (presumably due to wind-snow effects upon the exposed crown). Tops of at least two-thirds of Abies magnifica and half of Pinus contorta had been severly damaged at least once. In the herb stratum Lupinus breweri is conspicuous (approximately 20% cover) among a floristically poor assemblage of widespread species characteristic of poorly developed coarse sandy soils: Streptanthus tortuosa, Calypteridium umbellatum, Collinsia parviflora and Eriogonum sp. (Table 1). Unlike red fir forest, there is marked variability of subdominant taxa within different types of lodgepole pine stands.

Huckleberry oak scrub cover occurs over 63 ha, most of which is either open granitic outcrop with local soil accumulation, rocky crests of ridges, or steep slopes with south exposure. The principal region of Quercus vaccinifolia cover is a granitic outcrop with west to south exposure occupying

22 ha between 2,255 and 2,415 m elevation and extending nearly the full width of the upper Bourland Creek watershed (Figure 2). Here scrubby _Pinus jeffreyi_ possesses aspect dominance among patches of _Quercus vaccinifolia_ growing where topography has favored local soil accumulation. Total cover for _Quercus vaccinifolia_ and _Pinus jeffreyi_ is limited to usually less than 30 and 10%, respectively (plot 10, Table 1). Where significant soil accumulation has occurred along the northwest boundary of this outcrop an open forest of _Pinus jeffreyi_ with _Quercus vaccinifolia_ understory and occasional _Abies concolor_ has developed (see plot 15; Table 1 and Figure 3). The remaining 30 ha of _Quercus vaccinifolia_ scrub is primarily concentrated along rock-exposed ridge crests and is characterized by _Quercus vaccinifolia_ interspersed with widely spaced, establishment limited, _Pinus jeffreyi_, _P. monticola_, and _P. contorta_ (Figure 2). _Abies magnifica_ assumes aspect dominance within _Quercus vaccinifolia_ scrub where deeper soil has favored dense development of huckleberry oak. Presence of red fir is apparently due to moderation of seedling microhabitat afforded by increased scrub cover. One huckleberry oak stand on a 28° slope with south exposure just above Bourland Meadow (2,240 m elev.) possesses _Quercus kelloggii_ growing near its upper altitudinal limit (plot 3).

Populus tremuloides (cover type 218) occupies an 29.5 ha area with southeast exposure in the approximate center of the proposed natural area (Figure 2). Features distinguishing the aspen grove from adjacent red fir forest are rocky terrain

strewn with boulders and location on the lower half of a km wide incline. Both features probably favor subterranean water movement within the *Populus* grove.

Cover and basal area of *Populus tremuloides* are low, although frequency is high, approximately 670 stems/ha at plot 5 (Figure 3). Combined effects of light deciduous cover and mesic conditions with southeast exposure is a floristically rich assemblage of woodland and wet and dry meadow species (Table 1).

The remainder of the research natural area (34 ha) is meadow. Both "wet" and "dry" meadow types are recognized (labeled M and DM, respectively, in Figure 2). Examples of wet meadow vegetation are seen in plots 5, 19, and 22, while much dry meadow vegetation is included in plots 4 and 21 (Table 1).

Most meadow vegetation is of the "wet" type (27.5 ha). Bourland Meadow is particularly interesting as it has been subjected to heavy grazing. During the 1975 field study, cattle repeatedly entered Bourland Meadow resulting in such complete grazing that flowering specimens of most grasses and forbs could not be obtained. Present and past grazing has resulted in Bourland Creek cutting into the upper fourth of Bourland Meadow, causing this meadow to drain and precipitating an invasion of this region by *Pinus contorta*.

Growth

Growth rates for *Abies magnifica* vary widely according

to site aspect and stand structure. Growth of mature red fir may attain 0.41 m/yr between 20 and 100 years age at breast height on open sites with south exposure (plots 7, 9, 14: Figure 4). Sapling firs at these sites usually reach breast height (1.4 m) in 35 years and are 3 m tall within another 20 years (Figure 5). Median growth rates for Bourland Meadow red fir are approximately 0.35 m/yr between 30 and 110 years age at breast height. This growth rate is typical of red fir trees developing as part of a heavy stand on south exposure (plot 6), forested stands on gentle ridge crests (plot 1), young developing stands on north facing slopes (plot 17), and for firs growing within open sites with suboptimal edaphic or microclimatic characteristics (plots 8, 11, 18). Approximately 55 years are required for sapling firs of this site class to reach breast height (Figure 5). Least favorable sites for growth of individual Abies magnifica are dense stands regardless of exposure (plots 12, 16, 20). Mature trees only grow about 0.26 m/yr between 60 and 140 years age at breast height (Figure 4), and require another 80 years to attain breast height (Figure 5).

Growth of dominant Pinus contorta at wet meadow sites was approximately 0.16 m/yr between 20 and 70 years age at breast height (plot 19). Lodgepole pine on dry meadow sites grow about 0.13 m/yr during the same time interval if they do not incur top damage (plot 18).

Structure and Succession

When log densities per size class are plotted for

coniferous species occurring within Bourland Meadow Study Area, a nearly straight line relationship is derived for *Abies magnifica* (Figure 6), suggesting a stable all aged forest (Jackson and Faller, 1973). Only size class 2, saplings 40 - 122 cm tall and 25 - 75 years old (Figure 5), are slightly under-represented. Gaps and peaks in the log density per size class relationship for *Pinus monticola* and *P. contorta* occurring within the same forest suggest less stable episodic regeneration. *Pinus monticola* regeneration has been progressively declining for trees in size classes 3 through 1 (a decline which has probably been taking place for the last 70 to 120 years, the approximate age of size class 3 trees). Another gap and peak at size classes 7 and 8, respectively, suggest reproduction has been episodic for centuries (Figure 6). Reproduction of *Pinus contorta* has been even more episodic than in *P. monticola* with essentially no representatives for size classes 1 and 2 (seedlings to 122 cm tall). Survivorship curves for *Abies concolor* and *Pinus jeffreyi* (not mapped in Figure 6) also suggest highly episodic establishment with little current reproduction. Intolerance of pines to low light under an *Abies magnifica* canopy is the probable cause for the current reproductive failure of these species.

While size class distribution for all *Abies magnifica* sites suggests stability of this cover type, examination of individual 0.07 ha study sites reveals marked gap phase reproduction (Figure 7). Thickets of young *Abies magnifica*

and a few pines develop in patches where mature trees have been killed (usually through wind fall). Numbers of small saplings and seedlings begin to decline as young trees of the developing thicket attain dimensions of large saplings and samll trees (plot 17, Figure 7). This stage is apparently reached within 40 to 80 years after removal of the overstory. A few trees which may have been large saplings where crowns may have already been above the snow line at the time of overstory destruction grow rapidly and reach size classes 5 and 6 (48 to 128 cm dbh) within this time. As the young thicket transforms into a developing forest and finally a mature stand the gap in low to middle size classes widens as numbers of seedlings and small saplings progressively increases (plots 14 and 16, Figure 7). Without destruction of the overstory seedling and small saplings may remain in an "arrested" development, hence the low growth rate of saplings within all heavy fir stands regardless of exposure (see plots 16 and 20, Figure 7). Abies magnifica is, thus, a true climax species with regeneration normally triggered by death of mature firs, which typically occurs from windthrow. As a result the forest is a mosaic of different stem density (Figure 3) and size classes (Figure 7) the aggregate result of which is a stable forest. Insufficient light due to complete utilization of canopy space is the probable limiting factor in mature stands.

For scrubby Abies magnifica stands, space is not limiting. Log density per size class of these plots reveals flatter

curves than true forest sites. Generally low stocking densities, absence of larger size classes, and episodic regeneration of those size classes which are present all suggest a physically harsh site which is establishment limited. Open scrubby *Abies magnifica* sites do not differ from true *Abies magnifica* forests respecting either slope or exposure, suggesting infertile soil limits establishment and helps maintain an open site which further subjects those trees which do become established to wind and snow damage.

Evidence of large scale, primary succession also exists. *Abies magnifica* and, to a lesser extent, *A. concolor*, are advancing into those dry meadow sites which are not characterized by porous sandy soil (plot 21) into dry *Pinus contorta* forest (plots 4, 9), and into the *Populus tremuloides* grove (plot 5). *Pinus contorta* invasions of wet meadow sites is also conspicuous (plot 19) despite thinning efforts conducted along the southern boundary of Bourland Meadow. Observation further suggests a slow invasion of *Abies magnifica* into open *Quercus vaccinifolia* - *Pinus jeffreyi* sites like plot 10.

DISCUSSION

Red fir forests at Bourland Meadow Candidate Research Natural Area are representative of the cover type excepting associated species which possess an unusually large percentage of total basal area. Average basal area for 5,189 m^2 sampled in 11 separate red fir sites (plots 21 - 12 in

Figure 3) was 68.8 m^2/ha (306.5 ft^2/acre) of which 80% belonged to Abies magnifica. This compares to a range between 340.6 to 516.3 ft^2/acre (94 to 99% of which was red fir) for five Abies magnifica stands assessed by Oosting and Billings using 3,375 m^2 stand samples (1943). Lower basal area for Bourland Meadow red fir sites is doubtless a result of our seeking the full successional range of this species within the proposed Bourland Meadow Natural Area. Average basal area of the two fully developed red fir stands evaluated was 517.3 ft^2/acre (a figure equivalent to the maximum density reported by Oosting and Billings). However, only 91% of the Bourland Meadow total was Abies magnifica suggesting greater representation of associated taxa appears to be a consistent feature of this study area differentiating it from the stands of the former authors.

Abies concolor, Pinus contorta, and Pinus monticola each occur in three of 11 red fir sites studied (frequency percentage 27) while Pinus jeffreyi was important at only one site (Figure 3). Only at plot 12 did two associated species (Pinus contorta and P. monticola) occur together with Abies magnifica. This compares to an average frequency percentage of 13.5, 20.5, 42.0 and 0 for these same species using data of Oosting and Billings (1943), suggesting that Bourland Meadow red fir sites may be warmer and slightly more open that their red fir stands. Further evidence for this conclusion is the absence of Tsuga mertensiana at Bourland Meadow - a species normally occurring in Abies magnifica forest as a "straggler from higher altitudes" (Oosting and Billings, 1943).

Of 24 herbaceous species listed by Oosting and Billings as occurring in 6 or more of their 16 red fir study sites, 14 were found to be characteristic of Abies magnifica forest (see Table 1). Another 7 were widespread in Abies magnifica and other forest types: Collinsia parviflora, Monardella odoratissima, Gayophytum ramosissimum, Poa bolanderi, Calyptridium umbellatum, Silene lemonii, and Lupinus andersonii. The three species listed by Oosting and Billings which were absent at Bourland Meadow study sites are: Chimaphila umbellata, Plagiobothrys hispidus, and Castilleja pinetorum.

The primary effects of fire within red fir forest are a reduction in down litter, thinning sapling age classes, and slightly increasing the amount of sunlight reaching the forest floor, which renders the site more favorable for successful establishment of pines (Kilgore, 1971). Fire also promotes regeneration of senescent stands as trees injured by fire rot quickly, becoming weak and much more susceptible to wind throw (Gordon, 1973). Increased turbulence in a region where a blow down has occurred may cause the opening in the forest canopy to widen, initiating the type of stand succession discussed on pages 10-12.

Near absence of pine regeneration within the red fir forest, the absence of fire scars on mature fir trees, and lack of fire indicators like Arctostaphylos nevadensis (Oosting and Billings, 1943) all suggest fire has been relatively unimportant at Bourland Meadow since at least the turn of the century.

Invasion of bordering mesic and xeric _Pinus contorta_ communities by _Abies magnifica_ as well as the increased abundance of _Quercus vaccinifolia_ has been noted by other authors (Oosting and Billings, 1943; Heath, 1973) and appears to be a widespread phenomena within Sierra Nevada red fir forests. Establishment of a natural area on the uppermost watershed of Bourland Creek will preserve an excellent example of virgin red fir forest and provide a site to further assess long term changes in Sierra Nevada vegetation.

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Table 1. A partial list of sped s and potential species-plots groupings for forest vegetatation within Bourland Meadow Study Areas.

	3	10	15	13	8	18	21	7	6	14	11	9	17	1	20	16	2	12	4	19	5
Huckelberry Oak Scrub																					
Quercus vaccinifolia																					
shrub stratum	1	1	2	1																	
herb stratum	4	3	4	4						+			+		+			+	+		
Pinus jeffreyi																					
tree stratum		1	2		+					1		+									
shrub stratum	+	+	2																		
herb stratum			+											+		+					
Sambucus caerulea	+																				
Prunus emarginata	+																				
Quercus kelloggii	+																				
Asclepias sp.	+																				
Phlox diffusa		+	+	+																	
Eriogonum nudum		+	+							+											
Pellaea bridgesii		+	+																		
Lodgepole pine - Red fir Scrub Forest																					
Lupinus brewerii				+	2	4				+	+		+						+		
Red fir Forest																					
Ceanothus cordulatus							1	3													
Abies concolor																					
tree stratum							1	2	1	1											
shrub stratum			+					1											+		
herb stratum							+												+		
Abies magnifica																					
tree stratum					1	1	2	3	4	2	3	3	2	3	4	4	4	3			
shrub stratum	+			+	2	1	1	2	1	3	2	4	4	2	2	1	3	2	+	+	
herb stratum	+	+			2	+	1		+	2	+	2	2	2	1	1	1	2	+	+	
Erigeron peregrinus v. angustifolium	+						+	+	+	+	+		+			+					
Viola purpurea							+	+	+	+		+	+		+	+	+	+			
Erysimum asperum v. perenne							+	+	+	+		+						+	+		
Pedicularis semibarbata												+	+		+	+	+	+			
Smilacina amplexicaulis						+	+	+	+			+	+			+	+				+
Kelloggia galioides												+	+	+							
Thalytrichum fendleri							+	+				+	+			+	+				+
Chrysopus breweri								+	+				+		+	+		+			

Table 1. continued

	3	10	15	13	8	18	21	7	6	14	11	9	17	1	20	16	2	12	4	19	5
Corallorhiza maculata								+	+		+			+		+	+				
Hieracium albiflorum									+				+	+	+	+		+			
Phacelia hydrophylloides								+	+	+	+		+	+	+	+		+	+		+
Penstemon gracilentus	+													+						+	
Pyrolla picta									+					+							
Pterspora andromedia									+												
Pinus monticola																					
tree stratum																		2			
shrub stratum			+															+	+		
herb stratum											+							+			
Lodgepole Pine Forest																					
Pinus contorta																					
tree stratum					+	1						1			1	1	+	+	3	3	
shrub stratum				+	+	2									+		1	+	2	2	
herb stratum						1							+		+			+	+	2	
Umbelliferae																			+	+	+
Montia perfoliata																			+	+	+
Osmorhiza occidentalis																			+	+	+
Lingusticum grazii																			+		
Rumex paucifolius																			+		
Calachortus leichtlinii		+																	+		
Lupinus densiflorus																			+		
Brodea exioides v. lugens			+							+							+		+		
Castilleja lemonii																			+		
Cryptantha sp.	+						+			+									+		
Potentilla glandulosa																			+		
Dodacatheon alpinum																				+	
Sececio triangularis				+																+	
Veratrum californicum																				+	
Carex sp.																				+	
Juncus sp.																				+	
Melica sp.																				+	
Viola sp.																				+	
Bromus sp.																				+	
Gentiana																				+	
Erysimum																				+	

Table 1. continued

	3	10	15	13	8	18	21	7	6	14	11	9	17	1	20	16	2	12	4	19	5
Populus tremuloides																					
tree stratum																					2
shrub stratum																					1
herb stratum																					+
Cystopteris fragilis																			+		+
Lithophragma heterophyllum																					+
Trifolium sp.																					+
Mimulus sp.																					+
Solanum sp.																					+
Elymus glaucus																			+		+
Plagiobotrys sp.																					+
Oenothera sp.																					+
Polemonium sp.																					+
Delphinium sp.																					+
Lotus sp.																					+
Stachys sp.																					+
Widespread species																					
Collinsia parviflora	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1		+
Monardella odoratissima	+					+	+						+						+		
Gayophytum ramosissimum	+	+		+			+	+				+	+		+	+		+	+		+
Poa bolanderi		+	+									+	+				+	+	+		
Bromus marginatus	+			+			+		+	+			+		+	+	+		+		
Streptanthus tortuosa		+	+	+	+	+	+			+	+	+	+					+	+		
Calyptridium umbellatum		+		+	+	+	+			+	+	+	+					+			
Silene lemonii	+		+				+			+					+		+				+
Lupinus Andersonii				+			+			+	+		+			+		+	+		+
Pteridium acquilinum			+				+			+								+			
Linanthes										+											+

FIGURE CAPTIONS

Figure 1. Topographic gradients and location of 0.07 ha study sites within Bourland Meadow Candidate Research Natural Area.

Figure 2. Distribution of vegetation types within Bourland Meadow Candidate Research Natural Area. Letters stand for scientific names of dominant species: Ac, *Abies concolor*; Am, *Abies magnifica*; Pc, *Pinus contorta*; Pj, *Pinus jeffreyi*; Pm, *Pinus monticola*; and Qv, *Quercus vaccinifolia*. Capital letters M and DM stand for "wet" meadow and "dry" meadow, respectively.

Figure 3. Count-plot data for arboreal species within 0.07 ha plots at the Bourland Meadow Study Area.

Figure 4. Age-height relationships for *Abies magnifica* within the Bourland Meadow Study Area. Height is standardized to 100 years at 140 cm above the base of each tree (breast height). See text for descriptions of sites representative of different height-age classes illustrated.

Figure 5. Total age-height relationships for *Abies magnifica* saplings within the Bourland Meadow Study Area. See text for descriptions of sites representing different age-height classes illustrated.

Figure 6. Survivorship curves for three arboreal species within Bourland Meadow forests. Size classes are 1 (less than 40 cm ht), 2 (between 40 cm and 122 cm ht), 3 (greater than 122 cm ht but less than 5 cm dbh), 4 (greater that 5 cm but less that 15 cm dbh), 5 (greater than 15 cm but less than 40 cm dbh), 6 (greater than 40 cm but less than 60 cm dbh), 7 (greater that 66 cm but less than 91 cm dbh), 8 (greater than 91 cm but less than 117 cm dbh), 9 (greater than 117 cm dbh).

Figure 7. Survivorship curves for <u>Abies magnifica</u> within specific 0.07 ha study sites within Bourland Meadow red fir forest. Size classes are the same as for Figure 6.

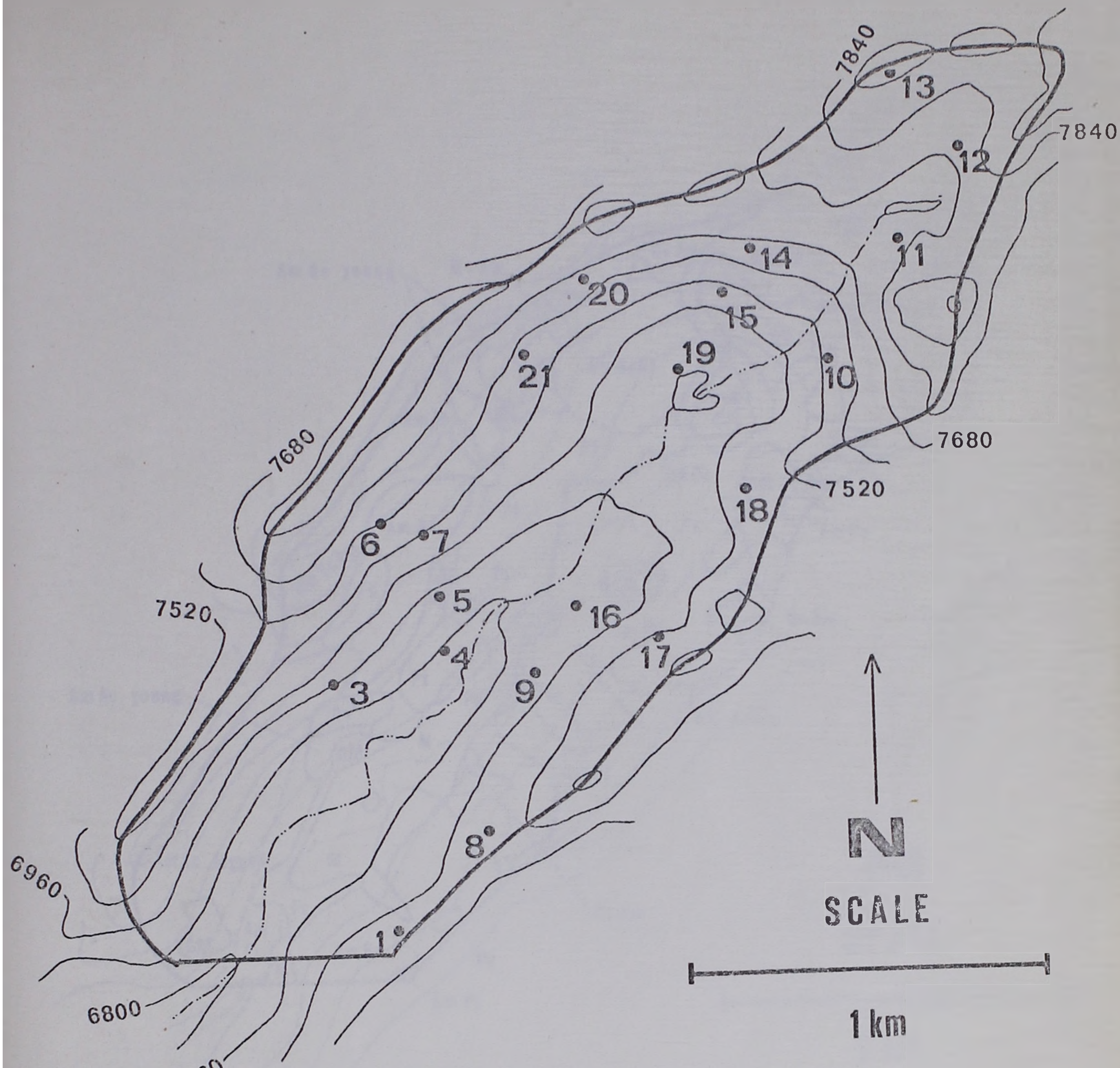
7840
13
7840
12
11
14
20
15
19
21
10
7680
7680
7520
18
6
7
5
7520
16
4
17
3
9
8
1
6960
6800
6960
N
SCALE
1 km

Figure 1

Figure 1

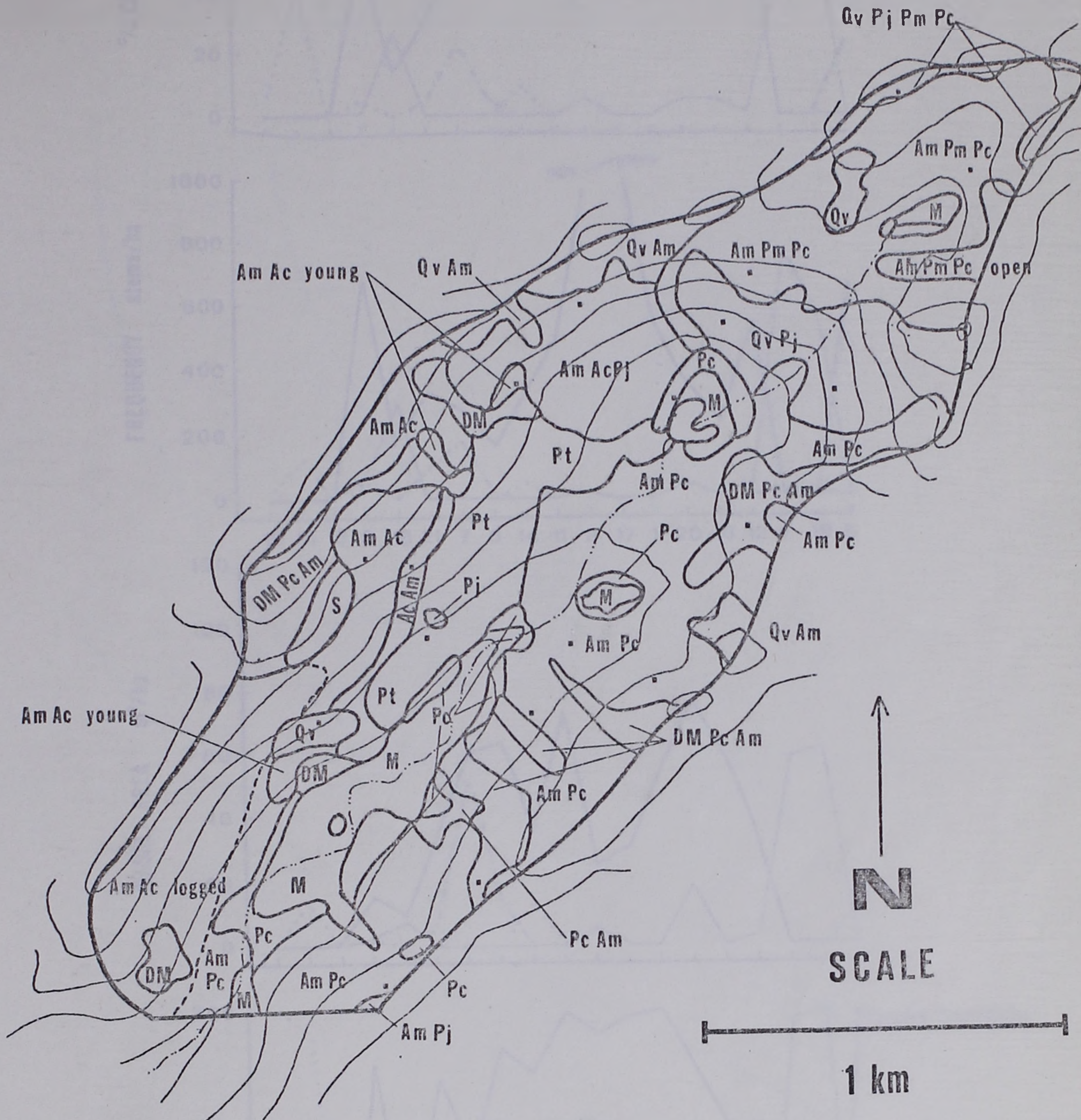
Qv Pj Pm Pc
Am Pm Pc
Qv
M
Am Pm Pc open
Qv Am
Am Pm Pc
Am Ac young
Qv Am
Qv Pj
Am AcPj
Pc
M
Am Ac
DM
Pt
Am Pc
Am Pc
DM Pc Am
Am Pc
Am Ac
Pt
Pc
DM Pc Am
S
Ac Am
Pj
M
Am Pc
Qv Am
Pt
Am Ac young
Qv
Pc
DM
M
DM Pc Am
Am Pc
Am Ac logged
M
Pc Am
Pc
DM
Am
Pc
M
Am Pc
Pc
Am Pj
N
SCALE
1 km

Figure 2

Figure 2

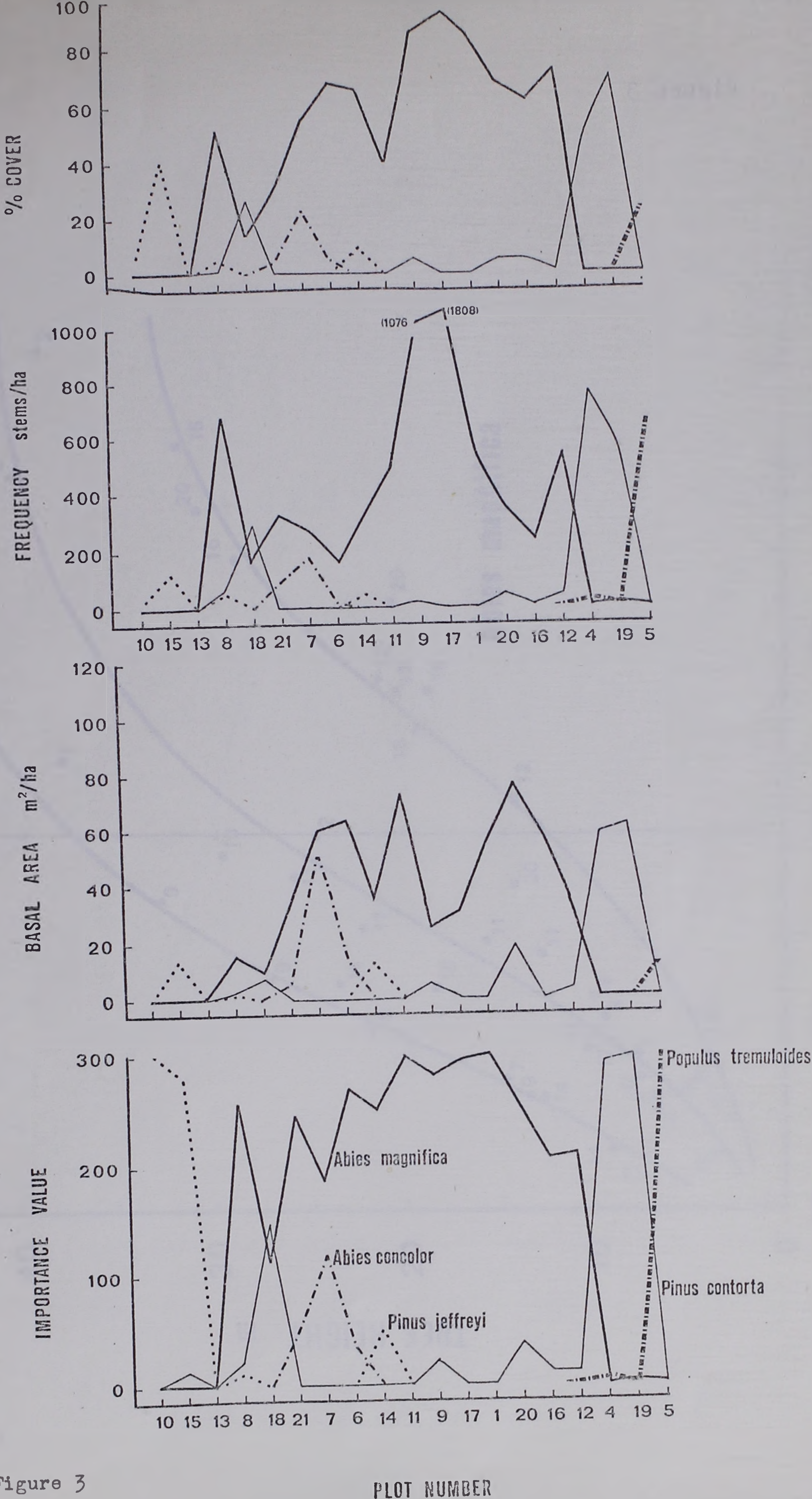
% COVER
FREQUENCY stems/ha
(1076
(1808)
BASAL AREA m^2/ha
IMPORTANCE VALUE
Populus tremuloides
Abies magnifica
Abies concolor
Pinus jeffreyi
Pinus contorta
10 15 13 8 18 21 7 6 14 11 9 17 1 20 16 12 4 19 5
PLOT NUMBER

Figure 3

Figure 3

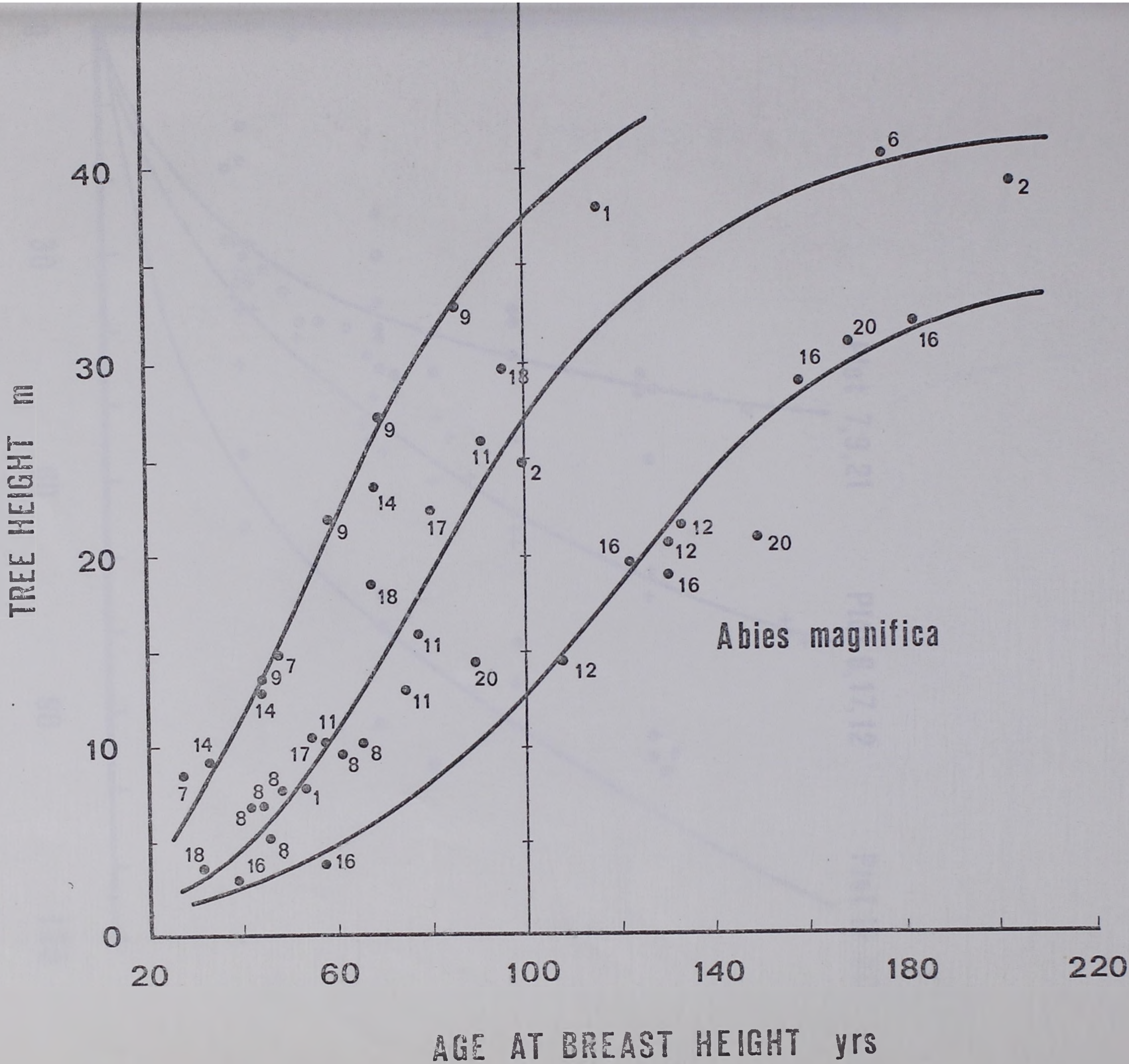
TREE HEIGHT m
AGE AT BREAST HEIGHT yrs
Abies magnifica
0
10
20
30
40
20
60
100
140
180
220

Figure 4

Figure 4

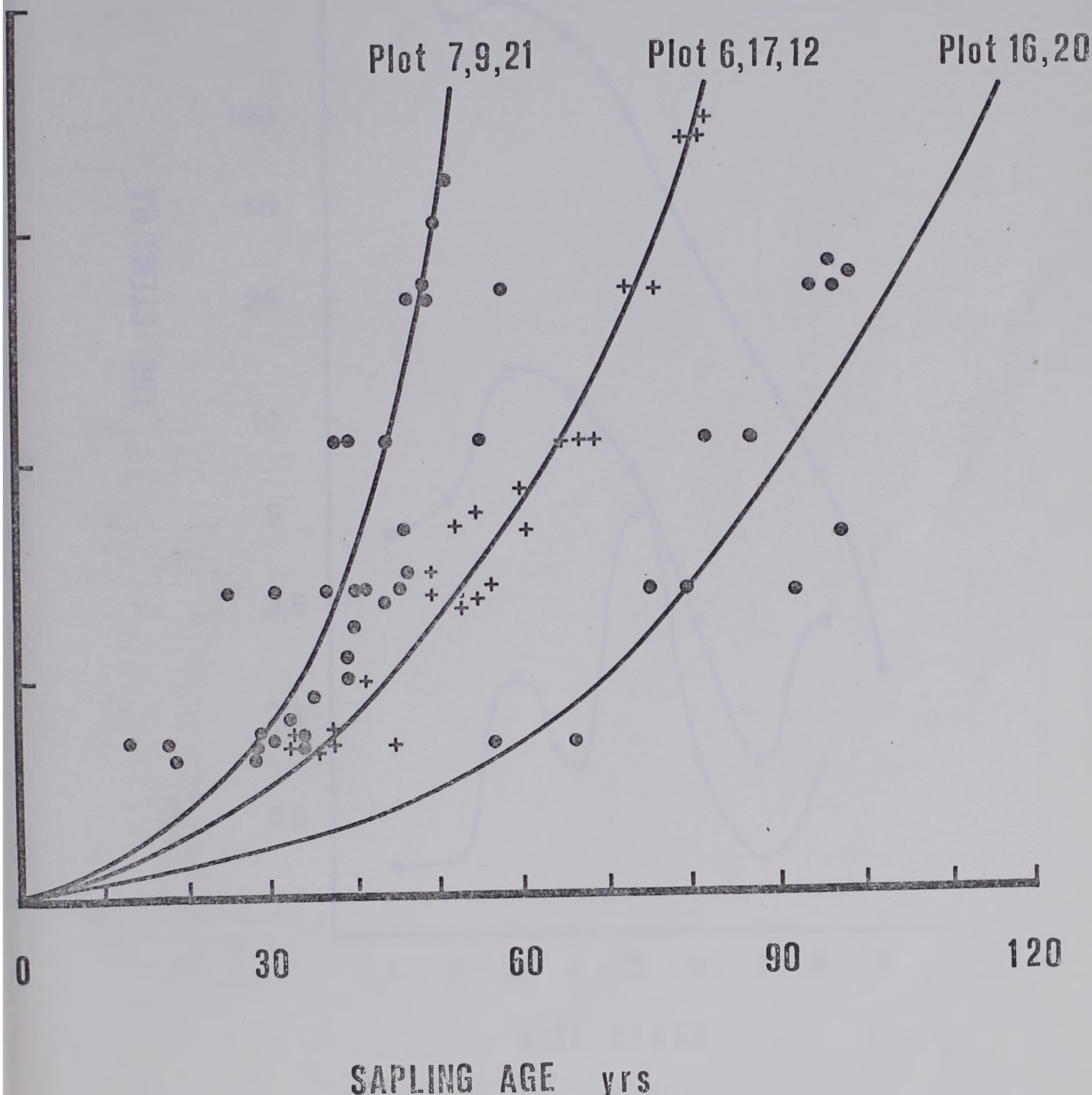

Figure 5

Figure 5

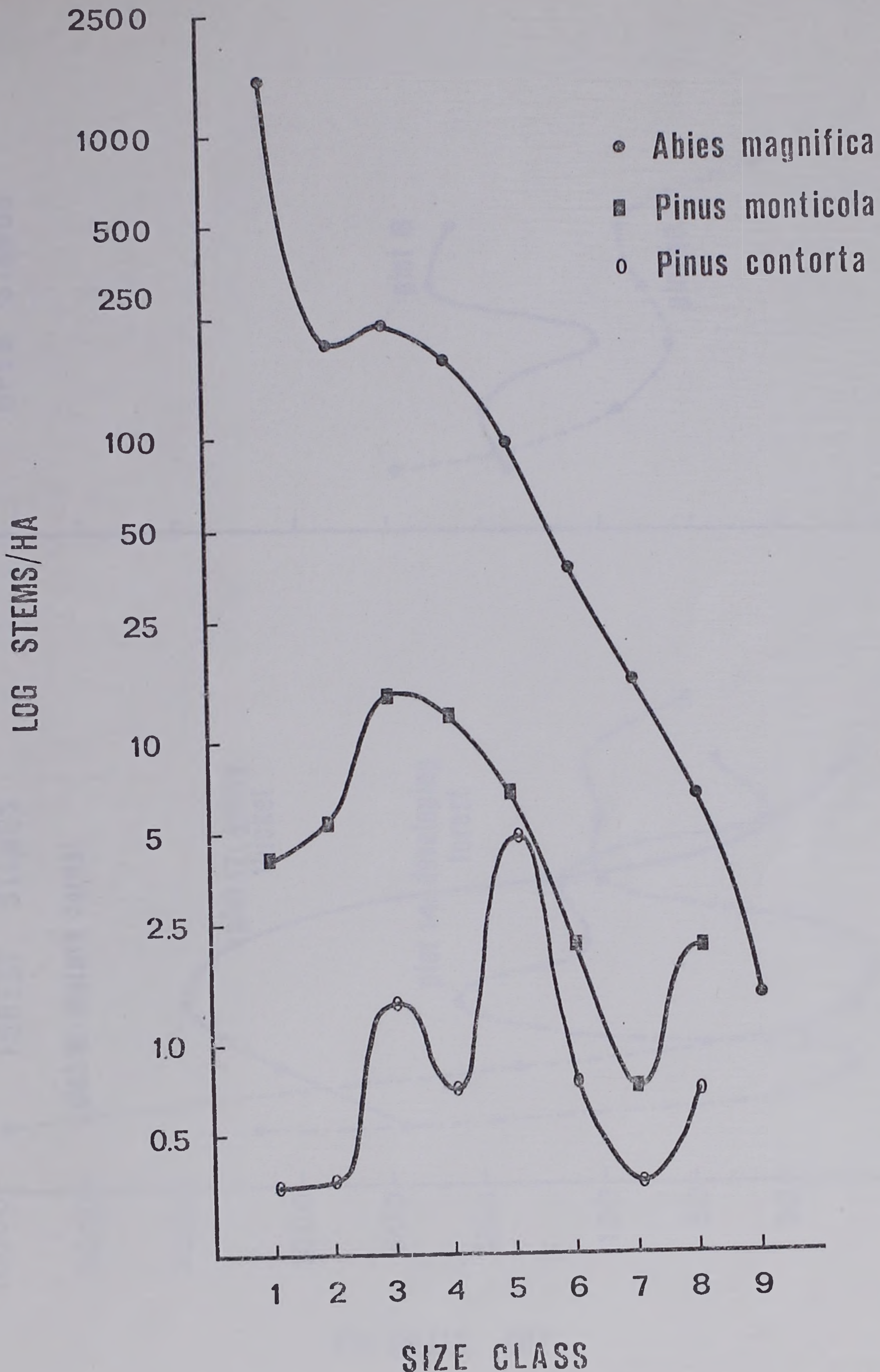
2500
1000
500
250
100
50
25
10
5
2.5
1.0
0.5
LOG STEMS/HA
Abies magnifica
Pinus monticola
Pinus contorta
1
2
3
4
5
6
7
8
9
SIZE CLASS

Figure 6

Figure 6

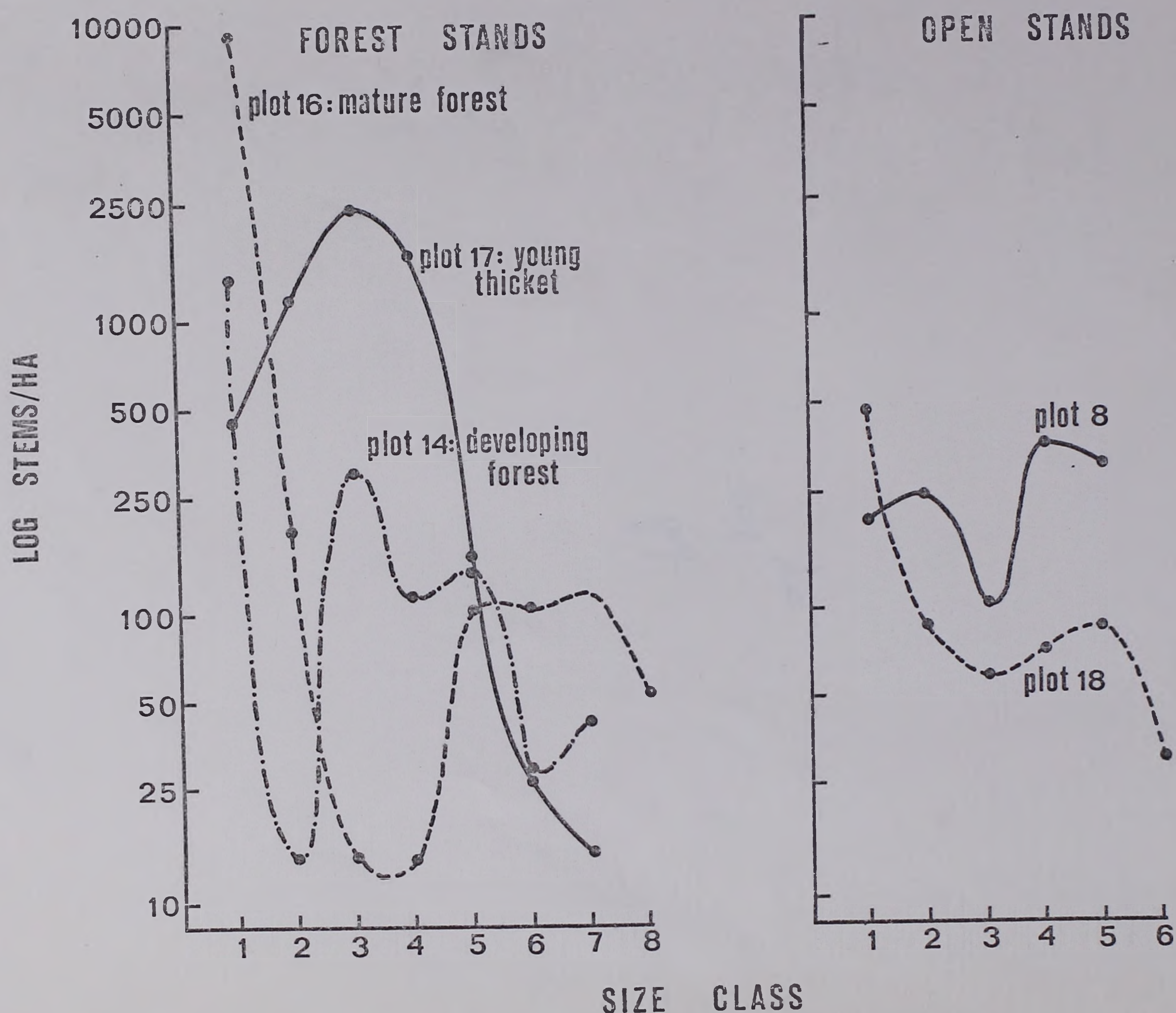
FOREST STANDS
OPEN STANDS
LOG STEMS/HA
10000
5000
2500
1000
500
250
100
50
25
10
plot 16: mature forest
plot 17: young thicket
plot 14: developing forest
plot 8
plot 18
1
2
3
4
5
6
7
8
SIZE CLASS

Figure 7